Rutherford County Tornado Hazard Preliminary Report: 1877 to 2002

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Introduction

"Tornadoes are one of nature's most violent storms. In an average year, about 1,000 tornadoes are reported across the United States, resulting in 80 deaths and over 1,500 injuries"[1]. In addition, tornadoes cause substantial economic losses. The Rutherford County Emergency Management Agency (RCEMA) contacted the Department of Mathematical Sciences at Middle Tennessee State University (MTSU) and requested assistance with performing a tornado risk analysis for Rutherford County. The analysis, to be conducted by the Mathematics Department during the Spring of 2003, will consist of two parts: (1) modeling the likelihood of a tornado occurrence and (2) measuring the cost of damage with respect to loss of life or limb, and property loss and/or damage which is associated with the tornado occurrence.

This paper provides some of the data collection and organization, and preliminary analysis to support the MTSU Mathematics Department project. First, this paper begins with a detailed explanation of the method of classifying tornadoes, called the Fujita Scale. Next, the Rutherford County tornado data, including property damage costs, is presented. Finally, some preliminary descriptive statistics for the Rutherford County tornadoes are presented.

Project Description

U.S. tornadoes are divided into seven intensity categories, which are labeled F0 through F6. This is the Fujita scale (also known as the Fujita-Pearson Scale) named for Dr. T. T. Fujita. The divisions are determined by the estimated maximum winds that occurred within the funnel [2]. The Fujita Scale is subjective and varies with the experience of the surveyor. A tornado receives its official F-Scale rating after it has already passed through an area. Personnel from the National Weather Service (NWS) office that issued the tornado warning survey the site to determine the F-Scale rating the tornado receives. Occasionally the NWS call experts in from other locations. Aerial surveys are also used when a violent tornado has occurred, to help determine the exact damage track. Insurance companies sometimes call in wind engineers to do their own evaluations. The tornado then receives its official rating from the National Weather Service [3, p 3,4]. Table 1 shows the Fujita Scale [3, p 2].

Table 1. The Fujita Scale

F-Scale Number	Intensity Phrase	Wind Speed	Type of Damage Done
F0	Gale tornado	40-72 mph	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	Moderate tornado	73-112 mph	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	Significant tornado	113-157 mph	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	158-206 mph	Roof and some walls torn off well constructed houses; trains overturned; most trees in forests uprooted.
F4	Devastating tornado	207-260 mph	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	Incredible tornado	261-318 mph	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged.
F6	Inconceivable tornado	319-379 mph	These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies.

Data were collected on tornadoes that have hit Rutherford County between April 1877 and April 2002. Tornado data for dates before 1877 are not available for Rutherford County from the available sources, which include the book by Thomas P. Grazulis titled "Significant Tornadoes, 1680-1991", and two different web addresses available through the National Oceanic & Atmospheric Administration (NOAA) website [5,6]. For each tornado, these data included (where available) the date, time, F-scale, path length, path width, deaths, injuries, and cost of property damage. Table 2 shows this tornado data for Rutherford County [4-6]. Since some of the tornadoes crossed county lines, the data in Table 2 are only for the Rutherford County portions of their paths. Individual cells, which are left blank, indicate data that are not available from these sources. Brief descriptions (where available) of individual tornadoes are included in the appendix [4].

Table 2. Tornado data for Rutherford County

Year	Month	Day	Time	F-Scale	Path Length (miles)	Path Width (yards)	Dead	Injured	Property Damage Cost ($)	Year Inflation Factor to Convert to 2002 $	Property Damage Cost in 2002 $
1877	April	18	11:00 pm	F4	40	500	10	50			
1883	April	22	12:00 pm	F3		200	1	2			
1890	March	27	9:30 pm	F2	10		0				
1900	November	20	6:00 pm	F3	25	200	9	40			
1909	April	29	11:15 am	F3	40		2	20			
1913	March	13	2:30 pm	F3	50		7	15			
1921	March	24	4:00 pm	F2			0	3			
1921	April	16	5:00 am	F2			0	3	15,000	10.13	151,950
1925	March	18	5:45 pm	F3	20		1	9	30,000	10.36	310,800
1925	March	18	6:10 pm	F3	12		2	15			
1926	November	26	5:00 am	F2	2		0	0			
1935	March	25	7:00 pm	F3	22		1	15	15,000	13.23	198,450
1955	May	12	5:58 pm	F1	0	20	0	0	25,000	6.76	169,000
1957	January	22	6:30 pm	F1	0	3	0	0	25,000	6.45	161,250
1963	March	11	4:20 pm	F2	2	100	0	5	25,000	5.92	148,000
1966	April	12	12:00 pm	F1	1	73	0	0	2,500	5.6	14,000
1974	April	3	5:10 pm	F3	16	100	0	0	200,000	3.68	736,000
1976	February	17	11:15 pm	F1	7	440	0	2	250,000	3.19	797,500
1976	February	17	11:15 pm	F1	6	440	0	0	250,000	3.19	797,500
1980	March	24	12:30 pm	F2	2	150	0	2	250,000	2.2	550,000
1980	April	8	10:46 am	F1	1	50	0	0	25,000	2.2	55,000
1984	May	7	1:30 am	F1	0	50	0	0	25,000	1.74	43,500
1984	May	7	7:00 am	F1	0		0	0	0	1.74	0
1995	January	28	3:55 pm	F1	3	50	0	0	50,000	1.19	59,500
1995	May	18	3:55 pm	F0	8	75	0	4	100,000	1.19	119,000
1997	January	24	4:37 pm	F2	5	440	0	0	500,000	1.13	565,000
1997	January	24	5:00 pm	F4	7	300	0	18	4,700,000	1.13	5,311,000
1998	June	2	2:15 am	F1	1	200	0	0	1,600,000	1.11	1,776,000
1999	August	12	4:00 pm	F0	0.1	5	0	0	0	1.09	0
2000	March	25	5:20 pm	F0	0.1	6	0	0	0	1.05	0
2000	May	24	11:50 pm	F0	0.4	10	0	0	0	1.05	0
2001	February	25	1:20 am	F0	0	10	0	0	0	1.02	0
2001	October	24	7:20 pm	F0	0	6	0	0	0	1.02	0
2002	April	28	6:34 am	F3	3.2	350	0	37	2,300,000	1	2,300,000

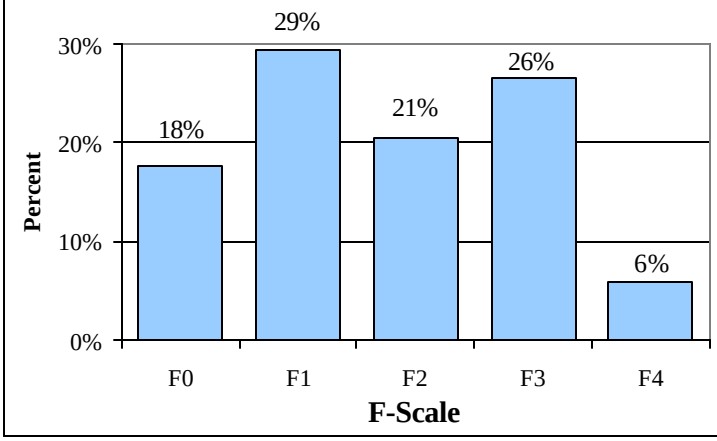
The data on the two tornadoes of 1976 did not agree between the different sources, therefore they were checked for validity. Contacting Mr. Mark Rose, of the National Weather Service office in Old Hickory, TN, resolved the discrepancy between sources. He stated that the discrepancy came about because several of the tornadoes crossed county lines, and some of the data counted the entire path, not just the Rutherford County portion. He advised that the order in which to use the sources is [4], then [5], then [6]. The data were then updated according to this precedent.

Results and Discussion

Between 1877 and 2002 there were 34 tornadoes reported in Rutherford County. In order to see how this number compares with the total number of tornadoes that occur throughout the state of Tennessee, the time period of 1950 – 1995 was examined. During this time there were 541 tornadoes reported for the state of Tennessee [7], with 22 of those occurring in Rutherford County. Therefore, about 4% of all of the tornadoes that hit the state occur within Rutherford County. While knowing the total number of tornadoes is important, it is the intensity of those tornadoes, and the casualties and property damage caused by those tornadoes, which are the focus of this paper.

Figure 1 (below) shows the breakdown, of the 34 Rutherford County tornadoes between 1877 and 2002, by intensity rating using the Fujita Scale. Tornadoes with an F-Scale rating of F2 or higher are labeled as "significant tornadoes", which usually means that these tornadoes have caused considerable damage. It can be seen that 53% of the Rutherford County tornadoes have been significant. It can also be seen that most tornadoes are F1, F2, or F3 (76%). Fortunately only 6% of all of the tornadoes that have hit Rutherford County, during the time period studied, have been "devastating tornadoes", F4, and there have not been any F5 or higher tornadoes. In this section, descriptive statistics for the Rutherford County tornadoes and selected data from Table 2 were used to generate Figures 1 – 7 and Tables 3 – 4.

Figure 1. Graph showing percent of tornados for each F-Scale.



Tables 3a and 3b (below) show the median path length and median path width compared to the average path length and average path width for each intensity rating. As might be expected, the path length increases as the intensity increases, with a noticeable leap from F2 tornadoes to F3 tornadoes. Yet when examining the path widths, it can be seen that the patterns are less predictable. For instance, F1 tornadoes have a mean path width of 147.3 yards, yet a median path width of 50 yards. This shows that the path width that a tornado has is less dependent on its intensity rating than its path length.

Table 3a. Median path length and mean path length for each F-Scale rating.

F-Scale Rating	Number of Tornadoes Used	Median Path Length (miles)	Mean Path Length (miles)
F0	6	0.1	1.4
F1	10	1.0	1.9
F2	5	2.0	4.2
F3	8	21.0	23.5
F4	2	23.5	23.5

Table 3b. Median path width and mean path width for each F-Scale rating.

F-Scale Rating	Number of Tornadoes Used	Median Path Width (yards)	Mean Path Width (yards)
F0	6	8.0	18.7
F1	9	50.0	147.3
F2	3	150.0	230.0
F3	4	200.0	212.5
F4	2	400.0	400.0

Table 4 (below) shows the median cost of property damage compared to the average cost of property damage for each intensity rating. As expected, the more intense a tornado is, the more property damage that it causes. The availability of this information is limited, particularly before 1926.

Table 4. Median and mean cost (in 2002 dollars) per intensity rating.

F-Scale Rating	Number of Tornadoes Used	Median Cost of Property Damage	Mean Cost of Property Damage
F0	6	0	19,833
F1	10	110,375	387,325
F2	4	350,975	353,738
F3	4	523,400	886,313
F4	1	5,311,000	5,311,000

In order to prepare for the possibility of property damage, RCEMA might be interested in knowing when tornadoes are more likely to occur, and their associated intensity rating. By first examining the months in which tornadoes occurred in Rutherford County, Figure 2 shows that tornado occurrences clustered around the months of March, April, and May, with 50% of the tornadoes occurring during March and April. There were no tornadoes for the months of July, September, and December.

Figure 2. Graph showing frequency versus month of occurrence.

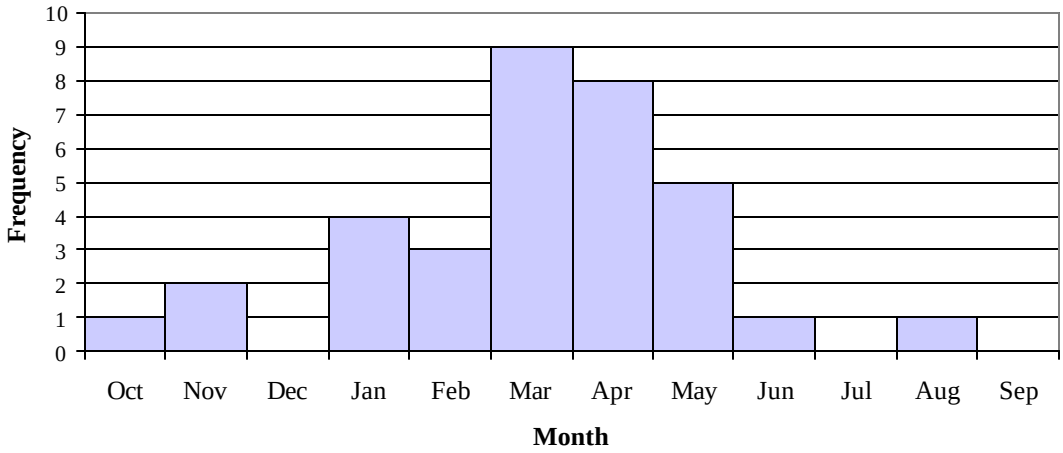
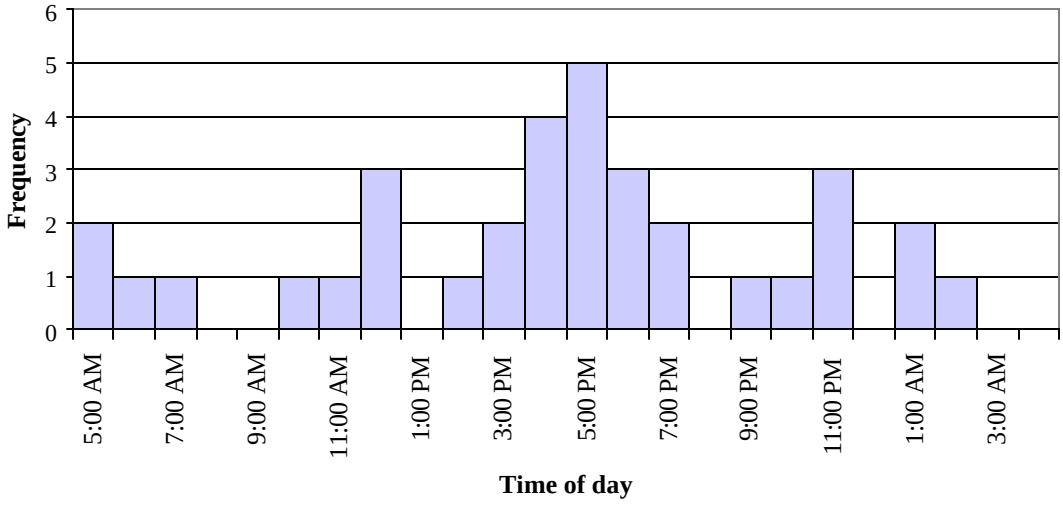


Figure 3 shows that tornado occurrences also clustered between the hours of 3pm and 8pm, with 50% of all of the tornadoes occurring during that time of day. The data implies there are peak times during the year and during the day when Rutherford County tornadoes occurred.

Figure 1. Graph showing frequency of tornadoes versus time of day of occurrence.



Next the tornadoes are grouped by their F-Scale rating to see when the significant ones occurred, those with an intensity rating greater than or equal to F2, and the amount of casualties and property damage that were associated with them. In Figure 4a, it is shown that significant tornadoes occurred between November and May, with the majority, 78%,

occurring in March, April, and May. Taking a closer look at this three-month period, Figure 4b shows that all categories of tornadoes occurred during this period, with 63% being significant.

Figure 4a. Graph showing frequency versus month and F-scale.

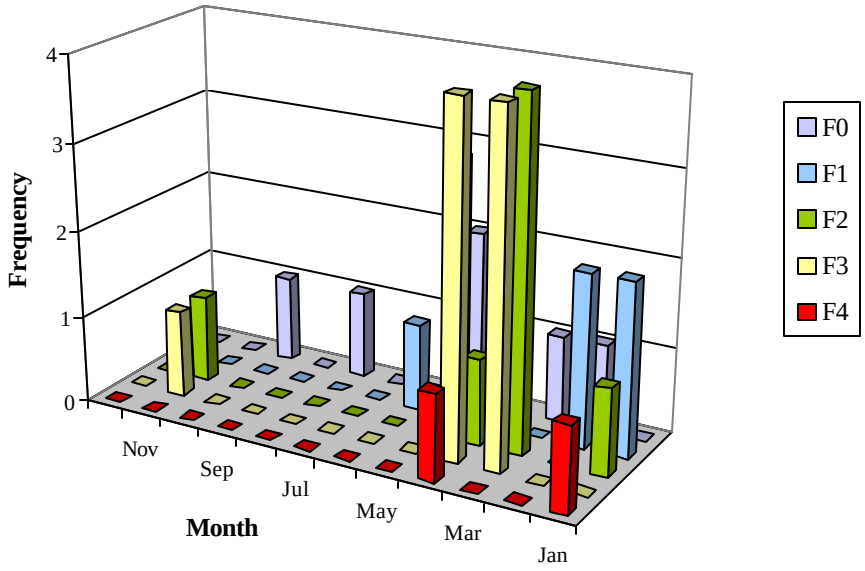
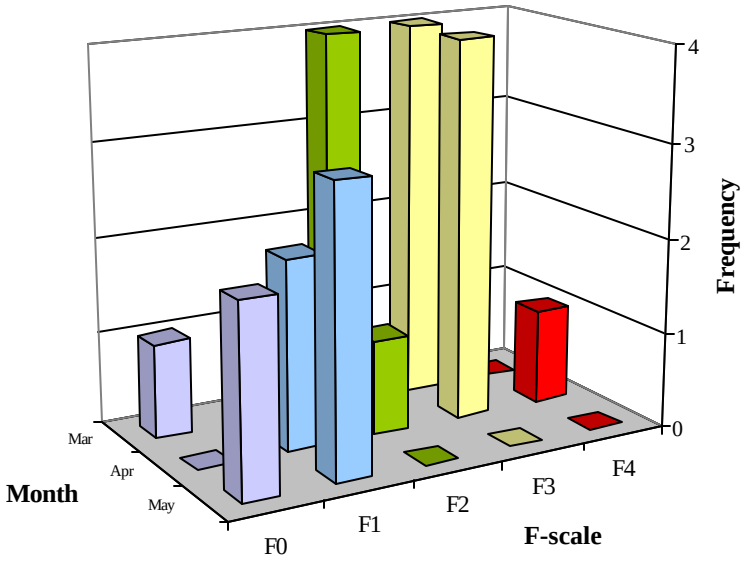


Figure 4b. Graph showing frequency of tornadoes versus month and F-scale.



The intensity rating also varied throughout the day, as shown in Figure 5a. However, when the peak hours of 3pm to 8pm are examined for intensity rating, Figure 5b shows that about 73% of those tornadoes were **not** significant. This shows that although about 50% of all of the Rutherford County tornadoes occurred during the hours of 3pm to 8pm, the majority of those are F1 or F0 tornadoes.

Figure 5a. Graph showing frequency of tornadoes versus time of day and F-scale.

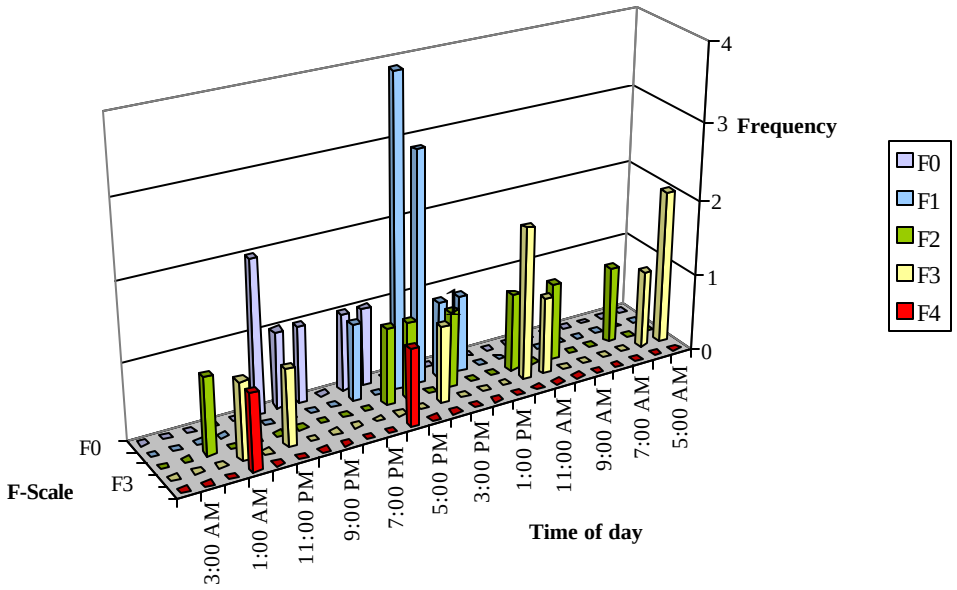
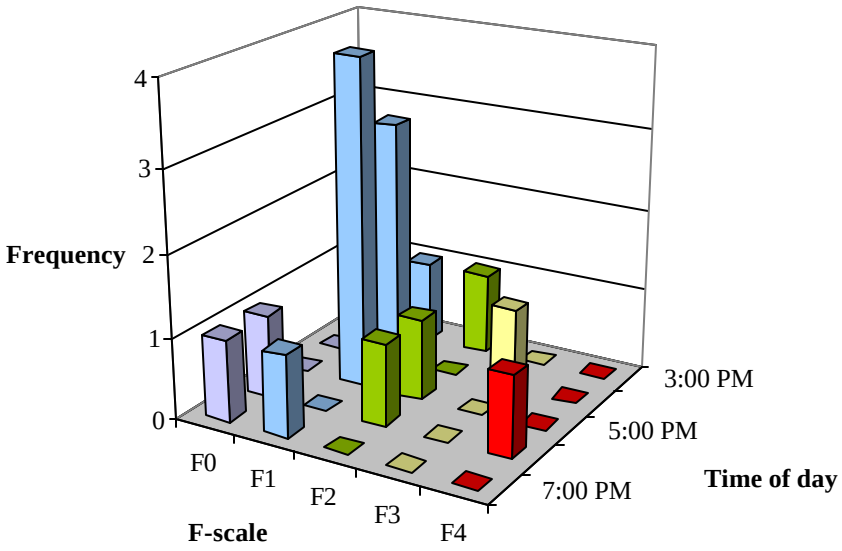


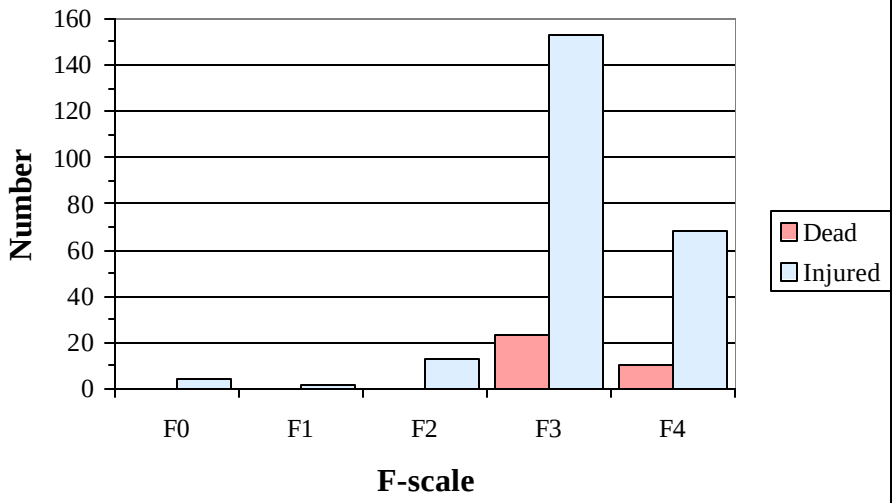
Figure 5b. Graph showing frequency of tornadoes versus time of day and F-scale.



From Figures 4a – 5b it can be seen that significant tornadoes occurred throughout the day, but the majority occurred during March – May.

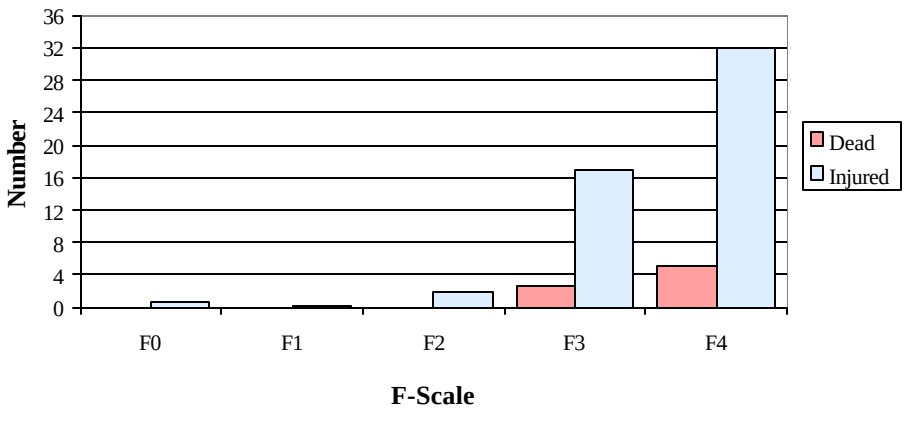
To try to prevent injuries and deaths, which result from tornado occurrences, it is important to know which tornadoes cause the most casualties. Figure 6 (below) shows the number of injuries and deaths that are associated with each F-Scale rating.

Figure 6. Graph showing number of deaths and injuries versus the F-Scale.



As expected (see Figure 6), there are few injuries and no deaths reported for the F0, F1, and F2 tornadoes, yet there are many more injuries and some deaths reported for the F3 and F4 tornadoes. However, in order to make a true comparison between the intensity of a tornado, and the resulting number of injuries and deaths **per** tornado must be calculated. Figure 7 shows this comparison.

Figure 7. Graph showing the average number of deaths and injuries per tornado versus F-Scale.



Clearly the stronger a tornado is, the more likely that injuries and/ or deaths will occur, with the greatest number of these being associated with F4 tornadoes. When examining the results showing the casualties and the property damage that are associated with the tornadoes, it becomes evident that the F2 through F4 tornadoes should be studied further.

Future Research

This collected data will be used to check existing probabilistic models of tornadoes. These models will include the Beta distribution, the Weibull distribution [8], and the Minimum assumption tornado-hazard probability model [9]. Once the best models are selected, they will be used to simulate and to predict the future occurrence of tornadoes in Rutherford County. These predictions for tornado occurrences will then be used to predict casualties and property damage/loss for Rutherford County. Hopefully these final results will assist RCEMA in formulating a tornado risk analysis plan for Rutherford County.

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Appendix: Description of Rutherford County Tornadoes Listed by Date

18 Apr 1877 (F4) – Moved E, passing 1 mile S of Newburg, 9 miles N of Columbia, 12 miles SE of Nashville, and eventually passing through and ripping apart the town of La Vergne. Damage was reported as very intense in valleys and less intense on hilltops.

22 Apr 1883 (F3) – A house was "swept from the earth" as a tornado moved NE across the southern part of the county. One person in the house was killed. Trees were mowed down "as if by an immense scythe".

27 Mar 1890 (F2) – Moved NE from Fosterville to SE of Murfreesboro. Homes were destroyed in the southern part of the county.

20 Nov 1900 (F3) – Moved NE from 5 miles S of Franklin to La Vergne. The tornado passed through Clovercroft, where three people were killed, through Nolensville, where three more people were killed, to La Vergne, where there were two deaths. It destroyed dozens of homes. All three communities were hit directly, and the contents of the small homes and stores were strewn for miles. A child was killed at Thompson Station, 5 miles SW of Franklin. Five other people may have died later.

29 Apr 1909 (F2) – Moved ENE from 4 miles SW of Nolensville, passing south of Smyrna, just north of Walterhill and ending near Statesville. Ten homes were destroyed. One person was killed near Nolensville and another near Walterhill. The entire town of Statesville had severe downburst damage. Thousands of trees were downed and cattle were killed. Some homes were reportedly destroyed in six counties further to the ENE, but tornadoes there are not confirmable.

13 Mar 1913 (F3) – Moved NNE from 10 miles E of Bodenham, passing near Brick Church. At least 10 homes were destroyed and 100 head of cattle were killed in the track across Marshall County. One death occurred near Wilson Hill, and another one 3 miles W of Lewisburg. In Rutherford County, five people died at a reunion in a home 3 miles SE of Eagelville. The damage ended, possible as a downburst, between Murfreesboro and Smyrna.

24 Mar 1921 (F2) – As with the previous event, what was apparently a pair of tornadoes (counted here as one event) touched down 5 miles SE of Murfreesboro. One home was destroyed and other buildings were damaged by one of the funnels. They were 500 yards apart, and no damage occurred in the space between them.

16 Apr 1921 (F2) – About half a dozen homes were torn apart on the county border near Readyville.

18 Mar 1925 (F3) – A man was killed in one of several tenant homes swept away as a tornado moved ENE, passing 2 miles NW of College Grove and through Kirkland. All casualties were at Kirkland. Eight small homes and 30 barns were damaged or destroyed. F3 damage occurred at one larger home. "Every vestige of plant life was torn from the ground".

18 Mar 1925 (F3) – Moved ENE from near Unionville to 2 miles NE of Fosterville. At least 10 homes were destroyed, and a woman and a young boy were killed in two.

26 Nov 1926 (F2) – Moved NE, destroying a church and the railway station at Florence. Minimal F2.

25 Mar 1935 (F2) – Moved E from 6 miles ESE of Murfreesboro, passing 3 miles S of Readyville and 3 miles S of Woodbury. Over a dozen homes were unroofed or destroyed. A boy was killed in a home south of Woodbury. Another death in Rutherford County was from a heart attack, and is not counted.

11 Mar 1963 (F2) – Moved NE in Versailles. Five farm buildings were destroyed, and two homes were damaged.

3 Apr 1974 (F3) – Moved ENE from 5 miles NW of Murfreesboro, passing west of Lascassas and ending near Statesville. Damage was near-F-4 intensity to three homes that were completely destroyed.

24 Mar 1980 (F2) – Moved NE in NE Murfreesboro. The Oakland High School gym was damaged. A boy at the school was hurt when he was blown into a flagpole. About 30 homes and eight businesses were damaged or destroyed.

24 Jan 1997, Worst tornado in Rutherford County (F4) – The F4 tornado struck the Southridge Subdivision, near Barfield at 5:03pm. The tornado caused 18 injuries and 4.7 million dollars in damage. One person had to be hospitalized over night. The tornado traveled 6.5 miles and had a maximum width of 300 yards. Forty-four homes were destroyed and 47 others damaged in the Barfield area. There was also damage to a middle school, Food Lion Supermarket, and the Chalet Apartments. The tornado first touched down on Yeargan Road, about 6 miles SW of Murfreesboro, with an intensity of F1 and a path width of 100 yards. At this location, a sheet metal roof was peeled off a barn and a couple of trees were uprooted in the area. The tornado moved NE and increased to F2 intensity with a width of 300 yards. As it struck the community of Barfield, an entire roof was lifted off a house, several homes were partially destroyed, and a barn was totally destroyed. The tornado crossed the West Fork of the Stones Fiver and struck the Southridge Subdivision. At this time, the tornado increased to its maximum intensity of F4, with the path width remaining at 300 yards. About half a dozen homes were totally destroyed. Then the tornado struck a large apartment complex just W of U.S Hwy 231, on the south side of Murfreesboro. The tornado produced some structural damage and extensive roof damage as it weakened to F1 intensity and its width decreased to 150 yards. The tornado crossed U.S. Hwy 231 and the Indian Wells Golf Course. Large trees were uprooted and structural damage occurred to several businesses as it approached I-24. The tornado continued moving NE across I-24, snapping and uprooting trees as the width narrowed to 50 yards. On the south side of Murfreesboro, near the intersection of Elam Road and U.S. Hwy 41, and near Brandyville Road and East Rutherford Boulevard, the tornado uprooted numerous trees and damaged the roofs of several homes. At this point, the tornado lifted back into the clouds. Newspaper accounts told stories of people going to a basement, or an interior room of a house or closet for safety. The low casualties from this tornado indicated the preparedness activities of the National Weather Service and local EMAs, combined with a long lead-time (41 minutes), paid off.